Environmental Impact Assessment

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Description

The premises of environmental impact assessment (EIA) lie in the Earth's limited environmental carrying capacity (Mebratu 1998; Meadows et al. 2005; Rockström et al. 2009; Steffen et al. 2015), the concept of sustainable development (WCED 1987), and the rise of public environmental awareness and concern (Jay et al. 2007). EIA first emerged as a formal process in the 1960s–1970s (Pope et al. 2004; Jay et al. 2007). Common applications of EIA include life cycle assessment (LCA) of product systems (ISO 14040: 2006; ISO 14044: 2006) and legislation-driven assessment of planned projects (Jay et al. 2007; Morgan 2012). EIA can take many forms in terms of the selection of environmental impact categories, impact indicators, and the spatiotemporal scope of impacts. EIA can serve as a preventive tool through which researchers, authorities, or decision-makers can better understand potential environmental impacts or identify current environmental hotspots within operations to improve environmental sustainability. Future EIA developments include quantifying positive environmental impacts (Sala et al. 2013; Dyllick and Rost 2017; Grönman et al. 2019), assessing environmental impacts and sustainability from a holistic, as opposed to reductionist, perspective (Ketola 2010; Laurent et al. 2012; Bjørn and Hauschild 2013), developing understanding about microlevel impacts on macrolevel environmental sustainability (Dyllick and Muff 2016; Ryberg et al. 2018a; Ryberg et al. 2018b; Kühnen et al. 2019), and performing regionalized assessments of environmental impacts within LCA (Mutel et al. 2019).

Synonyms

EIA

Introduction/History

The term environmental impact assessment (EIA) has a dual meaning in contemporary literature. It can take the form of a broad umbrella concept that encompasses assessments of the environmental impacts of various activities, organizations, products, or people, and related assessment methods. Second, EIA is often understood as a legislation-driven stakeholder-participatory procedure through which the environmental impacts of proposed projects can be assessed. Historically, these two EIA concepts have evolved from environmental/sustainability assessment research and legislation.

Generally speaking, the scientific justification for EIA and its normative background lie in the absolute limits of the Earth's environmental carrying capacity. Economist Thomas Robert Malthus (1766–1834) presented a theory of environmental limits that highlighted how resource scarcity represents a limit to growth (Mebratu, 1998). This concept was extended in 1972 when the Club of Rome acknowledged the planetary boundaries of economic growth in a report entitled "Limits to Growth" (Meadows et al., 2005). More recently, Rockström et al. (2009) and Steffen et al. (2015) quantified planetary boundaries and the safe operating space for humanity in their globally recognized research.

The early theories of limits to growth preceded the famous definition of sustainable development (Mebratu, 1998) that was published in the United Nations World Commission on Environment and Development (WCED) report, which is also known as the Brundtland report, "Our Common Future" in 1987 (WCED, 1987). The publication of the report represented a major political turning point (Mebratu, 1998) and fueled a wide-scale international debate. The more recent Sustainable Development Goals (SDGs) set by the United Nations established macro-level environmental sustainability targets (UN, 2015). Sustainable development is currently understood as a nested concept in which social and economic sustainability depend on environmental sustainability (Griggs et al., 2013).

The international standards of environmental management published by the International Organization for Standardization (ISO), in particular the standards on environmental life cycle assessment (LCA) of product systems, have widely contributed to how EIA is perceived. As a result of a participatory multi-stakeholder preparatory process, the first LCA standard ISO 14040, which covered the principles and framework of LCA, was published in 1997 (ISO 2019a), followed by a series of three further LCA standards (ISO 14040: 2006). ISO 14042, which was published in 2000, specifically addressed impact assessment (ISO 2019b) that is also known as life cycle impact assessment (LCIA) which is a mandatory phase of LCA (ISO 14040: 2006). Jolliet et al. (2004) first defined the overall framework of LCIA that presents the connections and available assessment methods and models between environmental pressures and impact categories (Jolliet et al., 2004; Verones et al., 2016). Currently, LCA is presented in ISO 14040 and ISO 14044, which were both published in 2006 (ISO 14040: 2006; ISO 14044: 2006). LCIA methods have actively developed since the 2000s (Hauschild et al., 2013; Mutel et al., 2019).

A specific and globally well-known application of EIA–to evaluate the potential environmental impacts of planned projects (such as industrial and agricultural activities, energy production, construction projects, waste management, traffic planning, or major changes to existing operations)–was originally designed in the late 1960s and early 1970s (Pope et al, 2004; Jay et al., 2007) in response to rising public environmental awareness and concern (Jay et al., 2007). This was fueled by the oil crisis and environmental disasters of the 1970s; for example, the Seveso accident in 1976. Principle 17 of the Rio Declaration on Environment and Development, which was set at the United Nations Earth Summit in 1992, further contributed to the implementation of project-related EIA within national policies (UN, 1992).. Public demand for this specific branch of EIA is high, and the EIA process has been widely implemented in legislation within both developed and developing economies (Jay et al., 2007; Morgan, 2012). This preventive EIA procedure facilitates the detection of potentially adverse environmental impacts of (major) projects, and authorities can withhold the permission to proceed in case of significant environmental risks (Jay et al., 2007). The EIA procedure includes hearings of potentially affected stakeholders (Glucker et al., 2013).

In parallel to the implementation of EIA in national policies, environmental issues were widely adopted within business in the 1990s (Ketola, 2010). Historically, the consideration of the negative impacts that production processes have on the environment has shifted focus from reducing end-of-pipe emissions to improving efficiency throughout the supply chain, and from a reductive to a preventive approach (Linnanen et al., 1997). Efficiency improvements typically reduce resource use and waste, thereby saving money for businesses and reducing negative environmental impacts. From the environmental sustainability management perspective, such efficiency improvements are business as usual (Ketola, 2010). Emerging business approaches to EIA involve the identification of the positive environmental impacts of existing or future products or services (Dyllick and Rost, 2017) and businesses’ contribution to macro-environmental sustainability (Dyllick and Muff, 2016).

Environmental impact pathways

The causes of environmental impacts can be categorized in different ways. In general, the subjects that are of interest in EIAs are individuals/consumers, commercial or non-commercial organizations, processes, products, services, projects, events, countries, societies, and/or policies. A consumption-based approach or a production-based/regional approach can be used in EIA; for example, while modeling national-level environmental impacts (UNEP, 2010). Environmental impacts are caused both by resource extraction from the environment (input to a process), such as materials or energy, and by releases into the environment (output from a process), such as pollutant emissions (ISO 14040, 2006; Verones et al., 2016).

EIA has the potential to depict impacts on a spatially and temporally wide range. Spatially, environmental impacts reach from local to global level (Jeswani et al., 2010). Some impacts are typical at a local level (for example, water scarcity), while some are global (for example, climate change). From the LCA perspective, a product system may cause environmental impacts globally, if the production processes of components, chemicals, energy, fuels, etc. are widely included in the system boundaries of the assessment. Similarly, the temporal scope of environmental impacts is broad, ranging from short-term to long-term impacts (Jeswani et al., 2010).

The EIA of projects considers the environmental impacts in the specific local context that the project is implemented in both the short and long term (Jeswani et al., 2010). In contrast, LCA is typically time and location independent (Jeswani et al., 2010). However, regionalization of the characterization of impacts in LCA has been actively developed during the past decade (Mutel et al., 2019) and environmental impacts are increasingly quantified based on specific local conditions rather than universal models.

Figure 1 depicts the causal impact pathway; i.e., how environmental pressures/interventions (UNEP, 2010), or using LCA terminology: flows across the boundaries of the system under assessment (ISO 14040, 2006), impact the environment; and how potential impacts are typically assessed, especially within LCA.

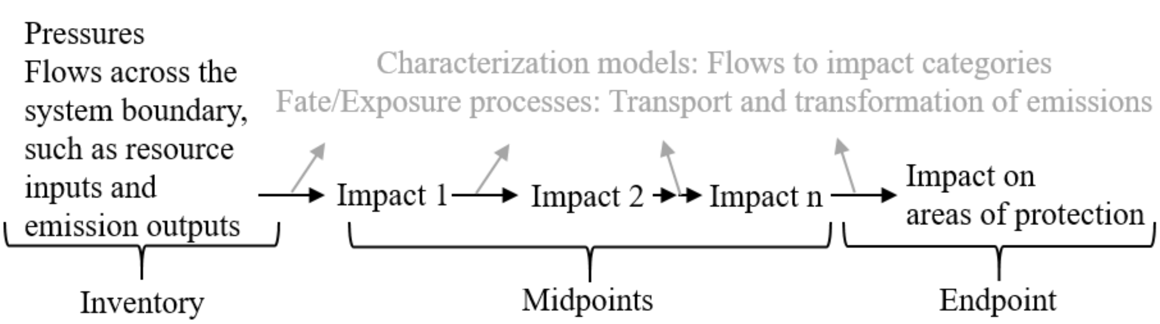

Figure 1. Impact pathway (Jolliet et al., 2004; ISO 14040, 2006; Finnveden et al., 2009; UNEP, 2010)

Environmental impacts can be direct or indirect, and the impact pathway can form a complex network. Therefore, the environmental impacts can be modeled at different points of the impact pathway. The modeling approaches employed in LCA are midpoint and endpoint modeling. Areas of protection describe different aspects of the environment that are ultimately affected or damaged when impacts reach the endpoint, at which they can be assessed. Typically, areas of protection include the quality of the natural environment, natural resources, man-made environment, and human health. (Jolliet et al., 2004; Finnveden et al., 2009.) The sensitivity of the receiving environment (ecosystems, animal species, plants, people) that is exposed to the pressure may determine the severity of the impact. LCIA characterization models aim to cover the relevant cause-effect chains/impact pathways/fate and exposure, and link the pressures to the environmental consequences (Frischknecht et al., 2016).

LCIA methods

The principles for carrying out LCIA in LCA are standardized in the ISO 14040 standard. In this part of the LCA, potential environmental impacts are quantified based on the life cycle inventory (LCI) results. In the goal and scope definition of an LCA study, the LCIA method, impact methods, and categories are typically selected. An LCIA method represents a set of LCIA impact categories. Typical LCIA methods are e.g. CML, ILCD, Eco Indicator 99, ReCiPe, and TRACI. Some of the LCIA methods provide a wide range of impact categories, but some are more concentrated to a narrower perspective, such as toxic impacts. LCIA methods consist of impact category groups–for example, eutrophication and ecotoxicity–and these groups may consist of one or several impact categories, such as freshwater ecotoxicity, marine ecotoxicity, and terrestrial ecotoxicity. Characterization factors are required to calculate the environmental impacts of a chosen category. Characterization factors define the extent of the impacts within the selected impact category due to inventory results in a defined unit. For example, according to IPCC (2007), the global warming potential impacts of greenhouse gas emissions can be calculated as carbon dioxide equivalents (CO2eq) using the following characterization factors: CO_2 1kg_{CO2eq}/kg_{CO2}, methane 25 kg_{CO2eq}/kg_{CH4}, and nitrous oxide 298 kg_{CO2eq}/kg_{N2O}.

Environmental impact indicators

EIA provides both quantitative and qualitative information about environmental impacts, typically in the form of quantitative and qualitative indicators, respectively. For example, in LCA, environmental impacts are quantified, whereas qualitative environmental assessment may require the inclusion of stakeholder panels who are interviewed to elicit insights into the perceived environmental impacts (Jeswani et al., 2010). Environmental impact indicators are widely applied in corporate environmental reporting, marketing, environmental product declarations, product labeling, benchmarking and environmental monitoring practices (Frischknecht et al., 2016).

Environmental indicators can be simple or more complex aggregate indicators (indices) (Heink and Kowarik, 2010). Quantitative indicators can further depict both the quantity and quality of the environment; for example, the impacts water extraction has on the water quantity available to other local users (water scarcity) or the impacts emissions have on water quality (water degradation) (ISO 14046, 2014). The UNEP/SETAC Life Cycle Initiative has been developing a globally harmonized set of environmental impact category indicators (UNEP, 2016).

When interpreting the significance of different environmental impacts, environmental impact indicators can optionally be normalized in LCA, which involves calculating the magnitude of the impact category indicator relative to reference information. Indicators can further optionally be weighted by converting, and possibly aggregating, indicator results across impacts. Impact categories may further be sorted and ranked. (ISO 14044, 2006.) One approach to evaluating environmental impacts is through monetary valuation of different environmental impacts. For example, a review by Förster et al. (2019) demonstrated the cost-if-lost approach to highlighting the economic value of ecosystem services, an approach that may be useful in political decision-making processes. Environmental management standards define environmental performance indicators (EPIs) that provide information on how an organization manages its potentially adverse or beneficial impacts on the environment. The organization may select key performance indicators among the EPIs that are especially significant. (ISO 14031, 2013.)

Footprints are typical environmental indicators that represent specific environmental impacts. They are used for reporting environmental performance. (Ridoutt et al., 2016.) Ridoutt et al. (2016) suggest that, while LCIA impact categories eventually affect areas of protection predefined by the LCA community, footprint metrics address the specific areas of concern defined by the interests of stakeholders. A variety of approaches can be employed to quantify various footprint indicators, both LCA-based and other, and harmonization has been attempted (Ridoutt et al., 2016). Although their scope is narrow, the quantification of LCA-based footprints shares features with the quantification of the more comprehensive environmental impact category indicators (Ridoutt et al., 2016). The two internationally standardized LCA-based footprints are carbon footprint (ISO 14067, 2018) and water footprint (ISO 14046, 2014). In the EU, the Commission has recommended the use of the LCA-based Product Environmental Footprint (PEF) methodology for assessing the broader environmental impacts of goods and services (2013/179/EU; JRC, 2019), and respectively, the Organization Environmental Footprint (OEF) method for assessing impacts at an organization level (2013/179/EU).

Alongside reducing negative environmental impacts, there is an increasing interest in creating and measuring positive environmental impacts (Bjørn and Hauschild, 2013), unburdening the environment (Kravanja and Čuček, 2013), positive footprints (Dyllick and Muff, 2016), net positivity (Dyllick and Rost, 2017), and environmental handprints (Biemer et al., 2013; Grönman et al., 2019; Kühnen et al., 2019). One of the most recent positive metrics to emerge is the LCA-based carbon handprint, which compares the carbon footprint of the users of a novel product/service with that associated with the use of a baseline product or service (Grönman et al., 2019). The carbon handprint, which is created if the novel product reduces the users' carbon footprint in comparison to the baseline product, is assigned to the novel product/service and its provider (Grönman et al., 2019). Norris (2019) presented a similar general definition of handprint.

Future directions

Some unresolved challenges remain in the field of EIA. Scientists have highlighted how, although sustainability and environmental management practices are becoming increasingly common in companies, the state of the environment is globally deteriorating (Dyllick and Muff, 2016). Thus, there is an inherent need to measure truly effective micro-level (for example, companies') contributions to macro-level (regional/global) sustainability (Dyllick and Muff, 2016); or vice versa, translate global environmental challenges or targets, such as the SDGs, into measurable and assessable micro-level actions (Muff et al., 2017).

A sustainability management challenge that contributes to the disconnect between the micro-level and macro-level environmental sustainability is that the EIA perspective tends to be excessively reductionist. LCA is, by default, a holistic approach in that it aims to expand the perspective from the environmental impacts of a single production process to the cradle-to-grave life cycle of a product, thus giving product designers and decision-makers information that can help avoid environmental problem-shifting between life cycle stages. However, the selection of environmental impact categories in LCA studies is often limited (Laurent et al., 2012). According to Ketola (2010) or Bjørn and Hauschild (2013), this represents a relative approach to environmental sustainability. In EIA, the focus has widely been on climate change impacts, although carbon footprint is deficient in representing environmental sustainability in terms of other environmental impacts (Laurent et al., 2012). Furthermore, Heijungs et al. (2014) stated that the environmental sustainability of isolated activities cannot be decided because absolute environmental limits can be established as planetary boundaries. That is, environmental sustainability is absolute and universal (Ketola, 2010; Bjørn and Hauschild, 2013). From the sustainability management perspective, a holistic approach to conducting EIA is required to avoid undesirable and unpredictable consequences and problem-shifting (Laurent et al., 2012).

Dyllick and Rost (2017) state that achieving true and universal product sustainability requires the assessment and optimization of the positive impacts of products. Earlier, Sala et al. (2013) concluded that LCA-based methodologies should be developed so that they can be used to enhance positive impacts while also fulfilling the traditional function of avoiding negative impacts. Recently, positive indicators have emerged, and this development is expected to continue. For example, area-of-concern-specific handprint indicators, in addition to the climate change-oriented carbon handprint (Grönman et al., 2019), are likely to emerge. The positive approach can further help to understand businesses' contribution to macro-level sustainability: Kühnen et al. (2019) developed a broader handprint methodology that considers the positive contribution businesses make to the SDGs. A future harmonization between different handprint approaches may be required, possibly through standardization.

Another recent attempt to decrease the gap between micro-level and macro-level environmental sustainability concerned the introduction of an LCIA methodology that is linked to the planetary boundaries and the absolute sustainability approach (Ryberg et al. 2018a; Ryberg et al., 2018b). This PB-LCIA quantifies the safe operating space occupied by the activities under assessment. The method can aid companies to understand the impacts of their activities with reference to the planetary boundaries and, thereby, make more macro-environmentally sound decisions. (Ryberg et al. 2018a.)

Abdoli et al. (2019) suggested a System-of-Systems (SoS) approach that was designed to offer a more comprehensive modelling of the environmental impacts of product systems through LCA. A SoS comprises the product system and the surrounding systems with which it interacts. The approach is intended to capture the rebound effects that are unforeseen in simple product system modeling. When rebound effects are included in LCA, the resulting total environmental impacts can be larger and more realistic than those impacts modeled directly from the product system. (Abdoli et al., 2019.)

Regionalized assessment of environmental impacts within LCA has the potential to increase the accuracy of LCA studies and reduce uncertainties in the quantified environmental impacts. Further development of regionalized EIA is expected. Challenges and development needs are related to regional data availability globally, lack of harmonization in determining and weighting the regionalized characterization factors of environmental impacts, insufficient quantification of uncertainty factors, and inconsistent metadata and data formats. (Mutel et al., 2019.) Furthermore, new impact categories are continually being developed within LCA. For example, Maier et al. (2019) recently presented a conceptual framework for the assessment of global value chain biodiversity.

Cross-references

Life cycle assessment

Carbon footprint

Carbon handprint

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